Observed Features on 9-cell Cavity RF Surface and Correlation with Gradient Failure Mode
- JLab Experience

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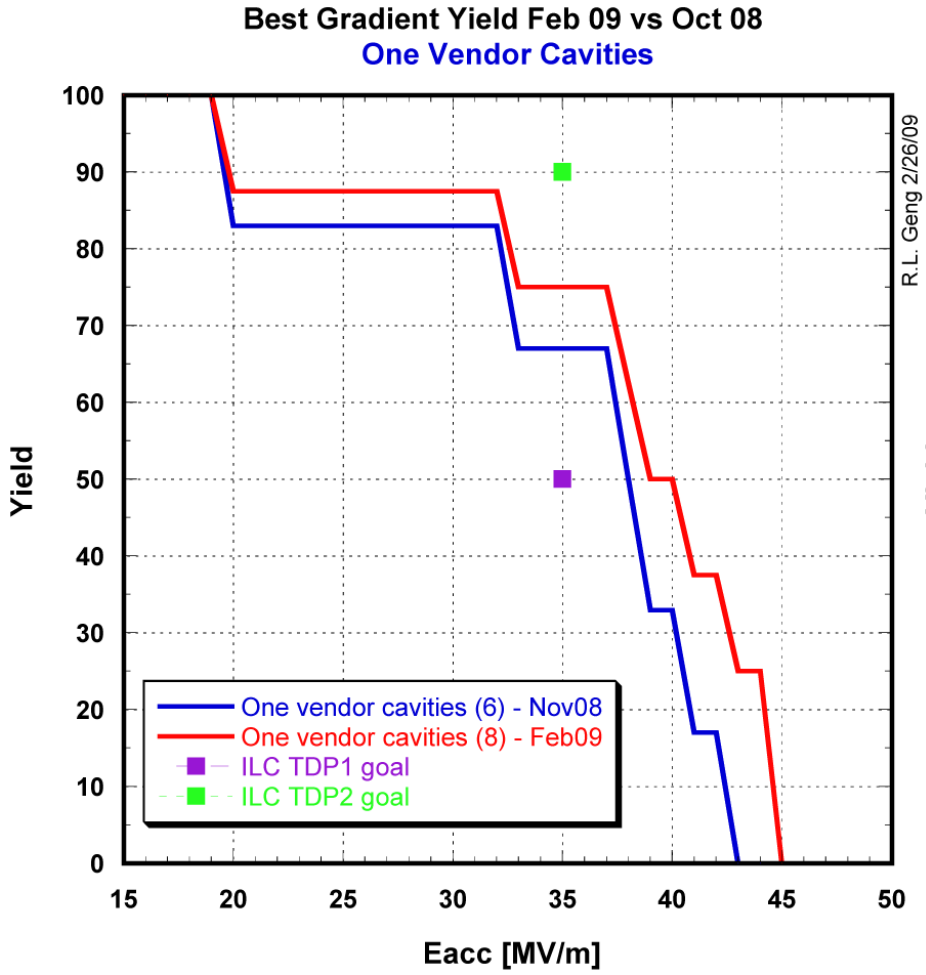
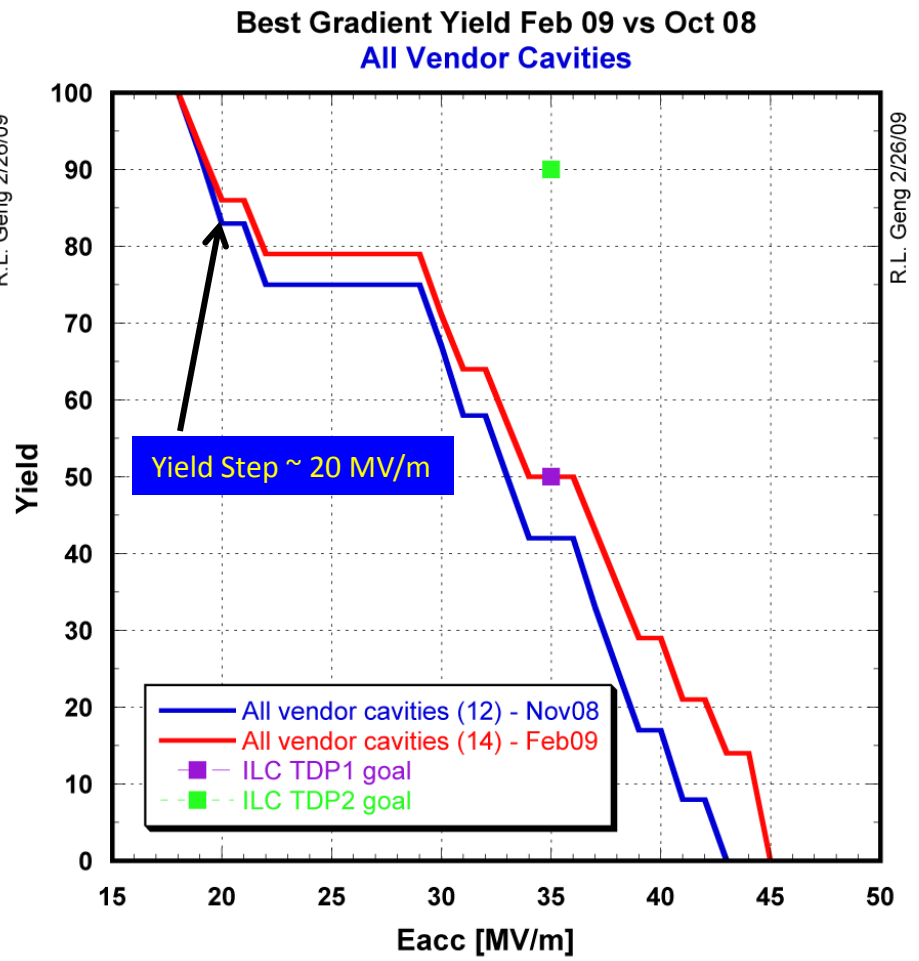
Jefferson Lab

March 6, 2009, Cavity Vendor Meeting at FNAL

Yield Curve – as of Feb 09

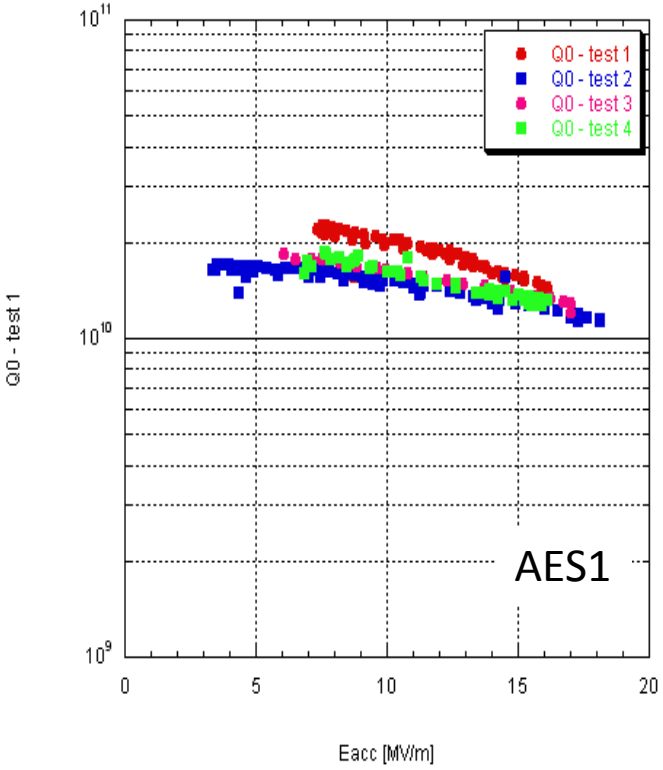
14 9-cell Cavities Processed & Tested at JLab





Earlier experience – Case #1

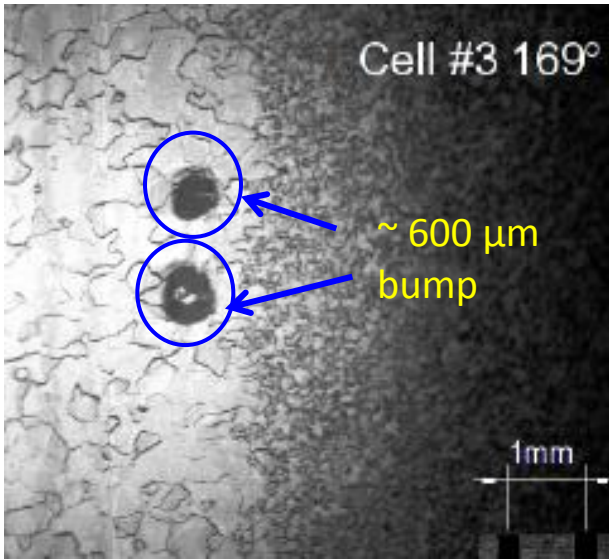
Quench Limit Unchanged by Repeated EP



- Test 1: 213 um EP, quench 17.5 MV/.
- Test 2: + 23 um EP, quench 18.0 MV/m.
- Test 3: + 16 um EP, quench 17.0 MV/m.
- Test 4: + 17 um EP, quench 16.0 MV/m.

Pass-band measurements during test 1,2,4 show consistently quench occurs in cell #3/7

Reported at AES Cavity meeting at Jefferson Lab, 8/28/07

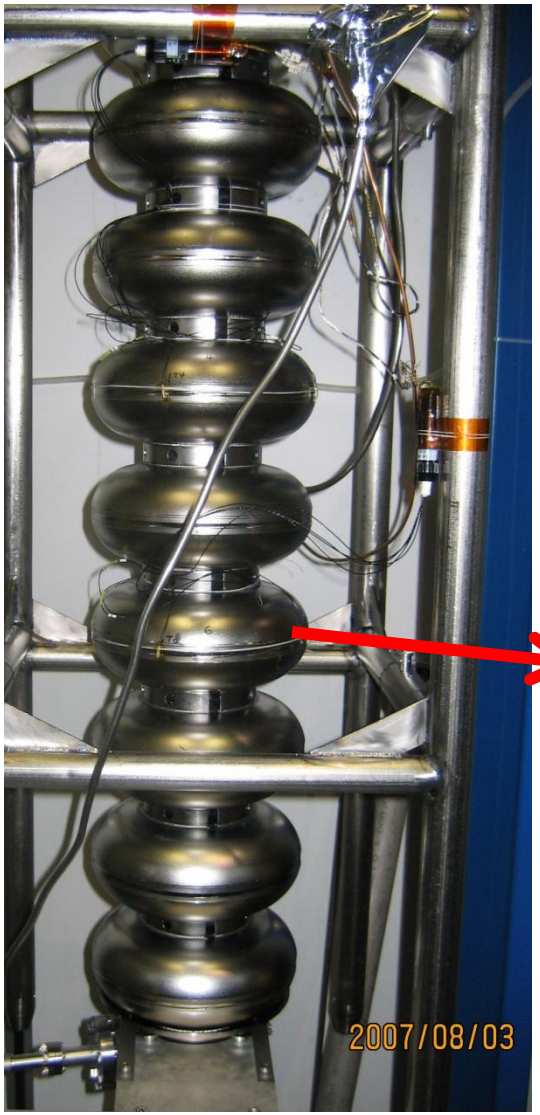


Ultimately, thermometry studies at FNAL and optical inspection at KEK correlated defects in cell #3 at HAZ edge of equator EBW

Iwashita et al., EPAC08 & Champion et al., ASC08

Earlier experience – Case #2

Quench Limit Unchanged by Repeated EP



- Test 1: 177 um EP, quench 18.7 MV/.
- Test 2: + 23 um EP, quench 17.6 MV/m.
- Test 3: + HPR, quench 17.0 MV/m.
- Test 5: + HPR + 23 um EP, quench 21.0 MV/m.

Pass-band measurements during test 2 indicated quench source in cell #4/6

Cell #4 singled out by using 8 thermometers during test 3

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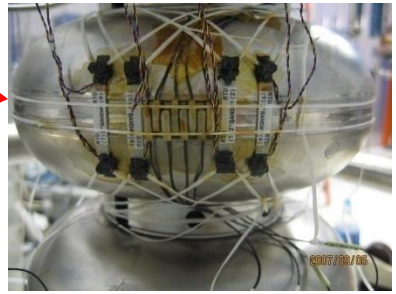
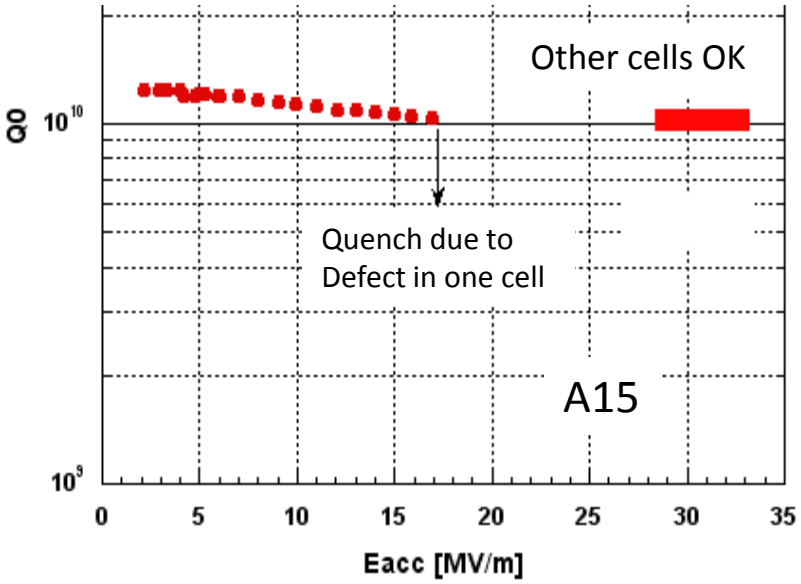


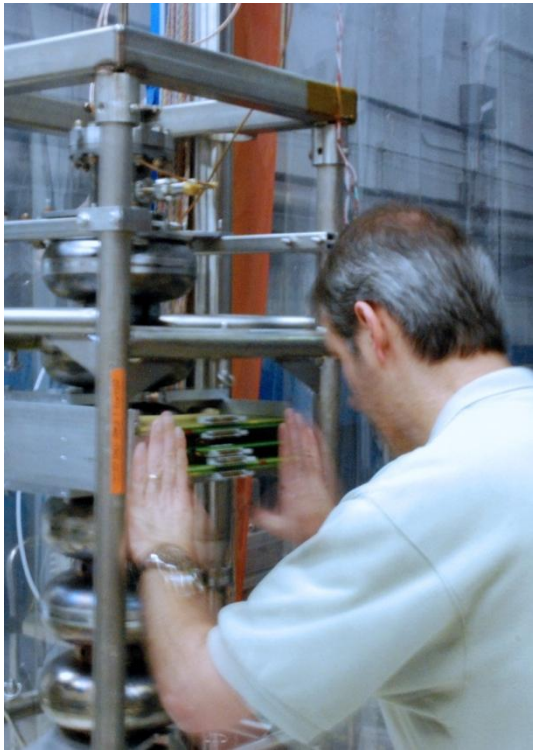
- Test 5 with more thermometers in suspected region of cell #4 identified hot spot near, but outside equator EBW.
- High-resolution optical inspection at identified hot spot region yet to be done.

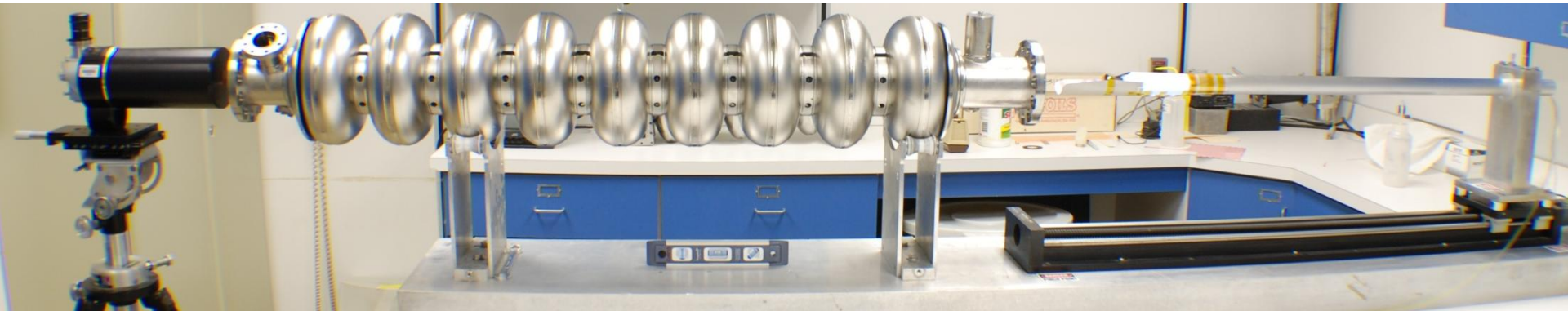
Similarity: outside equator EBW, away from overlap

More Recent Experience

T-mapping Quench Cell Pair & Quarter Inspection



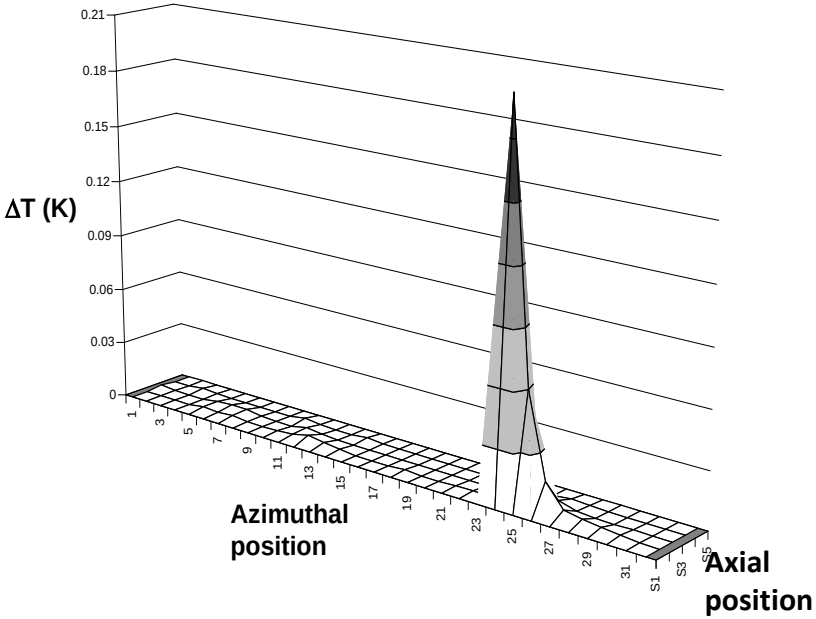


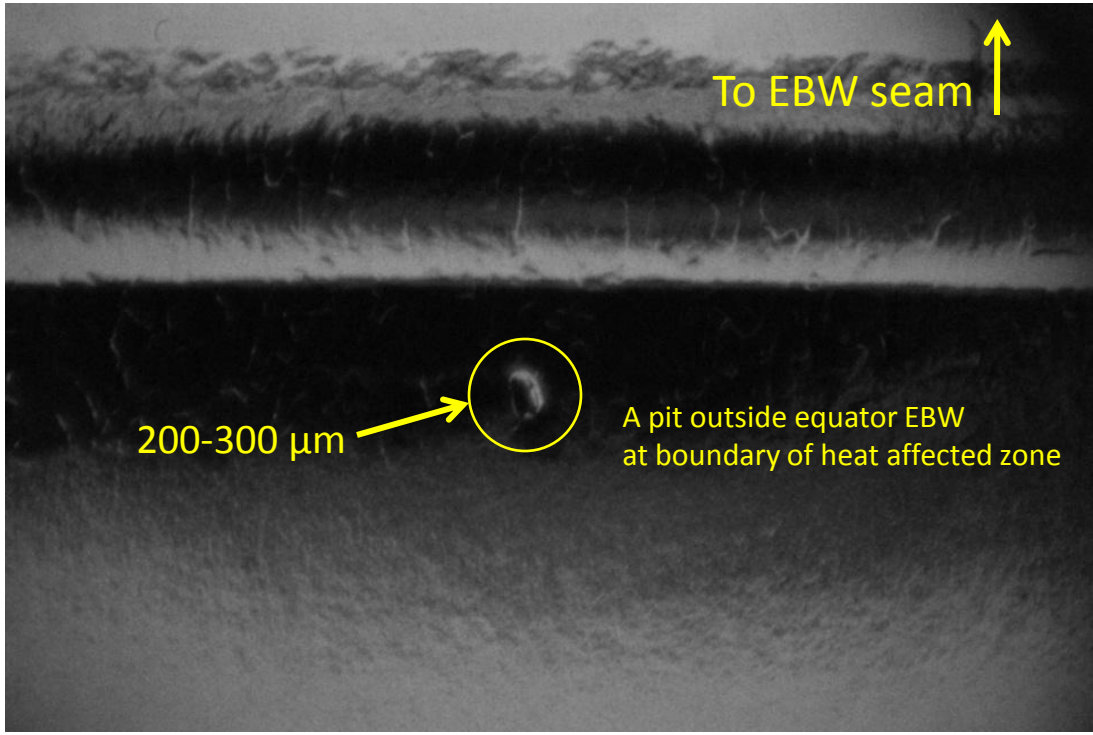


More Recent Experience (cont.)

Quench Source Located in Cell #3 – “hot spot”

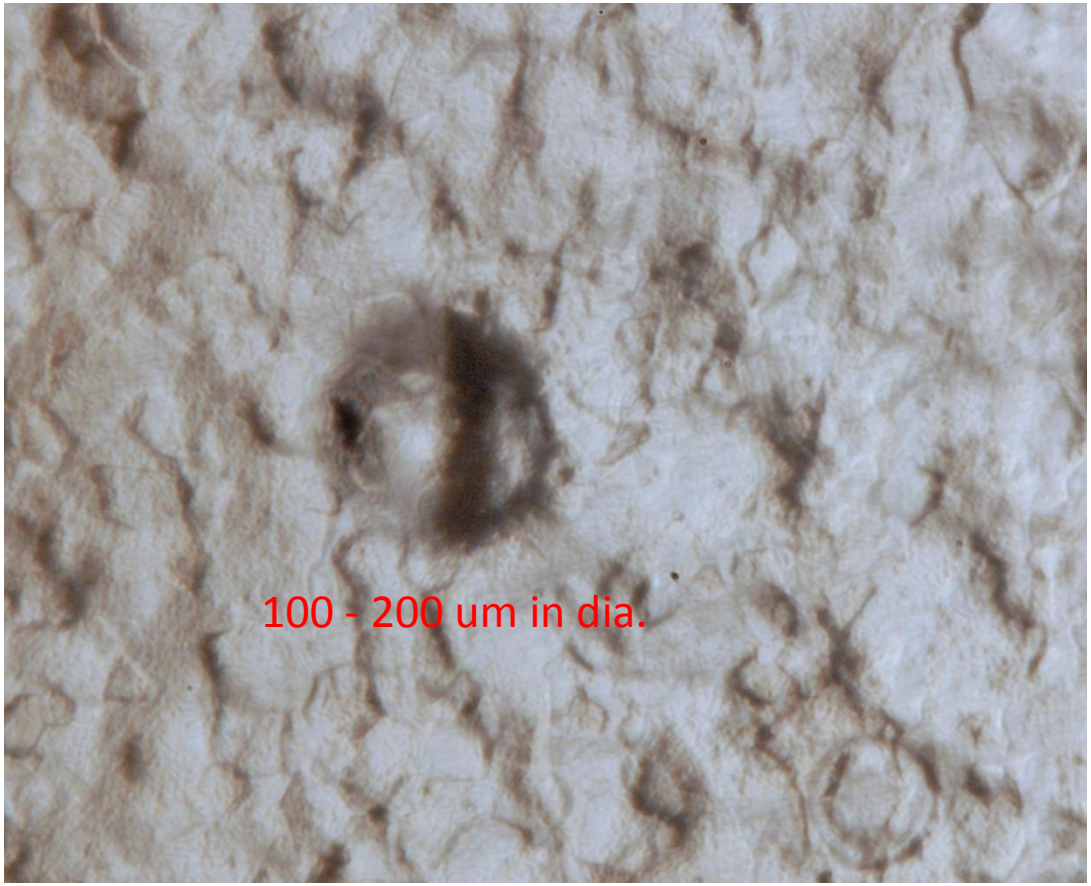
Pit Observed Within 1cm from Hot Spot





Defects in High E Region

Correlated to High Field Emission > 25 MV/m



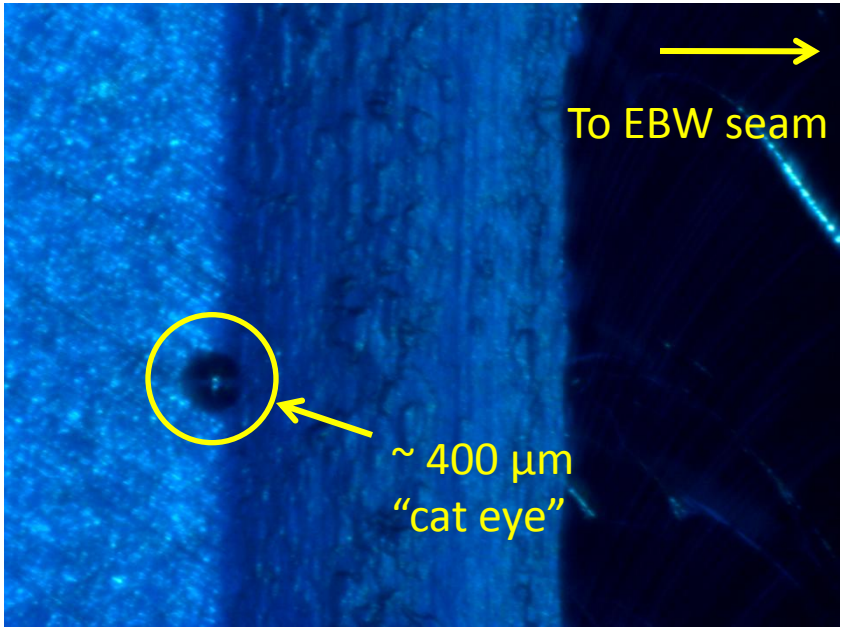
AES4 2nd half cell from long beam tube near stiffening ring radius

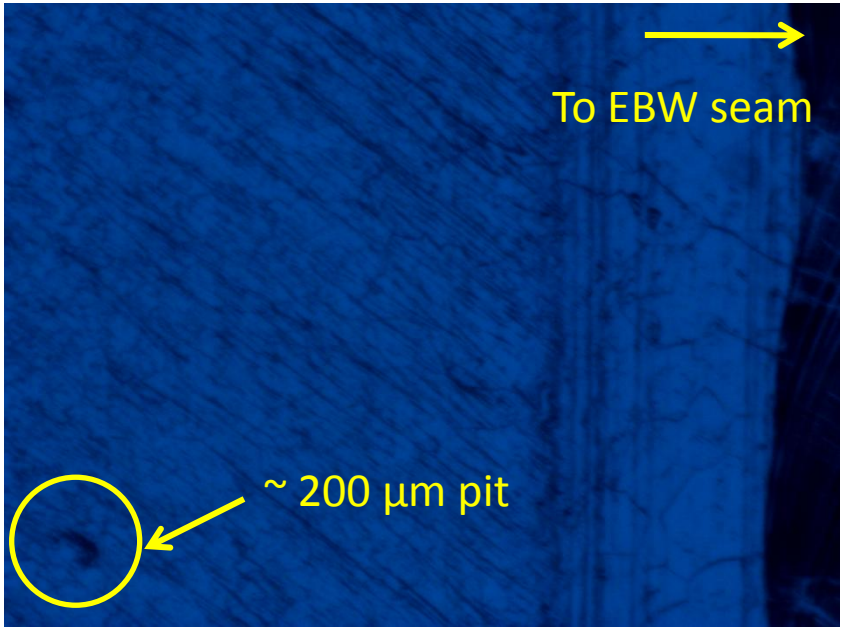
AES4 4th half cell from long beam tube near iris

Summary - I

- Quench limit causes a step near 20 MV/m in yield curve.
- Approximately 20% yield drop (3 out of 14 cavities).
- Quench limit insensitive to repeated EP.
- Quench source well correlated to T-mapping hot spot: in one region of one cell.
- Sub-mm defect (Pit/bump) observed in hot spot region.
- Defect is near, but outside, equator EBW (more precisely at the boundary of HAZ); azimuthally far away from weld overlap.
- Also observed on RF surface near iris weld & stiffening ring weld. There seems to be a correlation between these defects (happens to be in high E field region) and FE.
- It is hypothesized that the origin of these defects has somehow to do with Nb EBW.

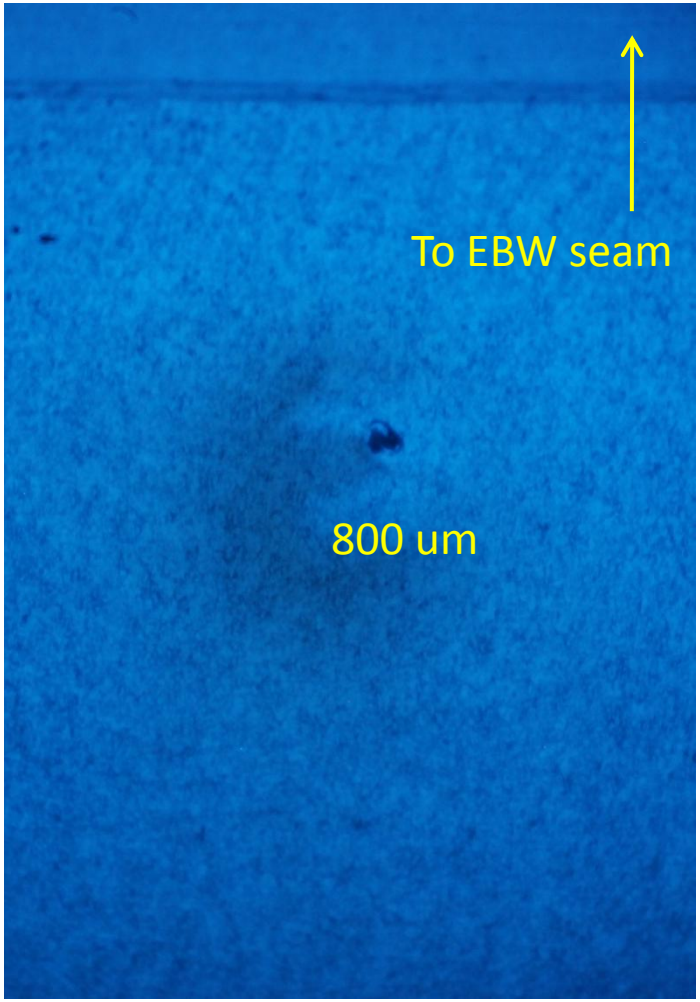
Optical Inspection of As-Built RF Surface

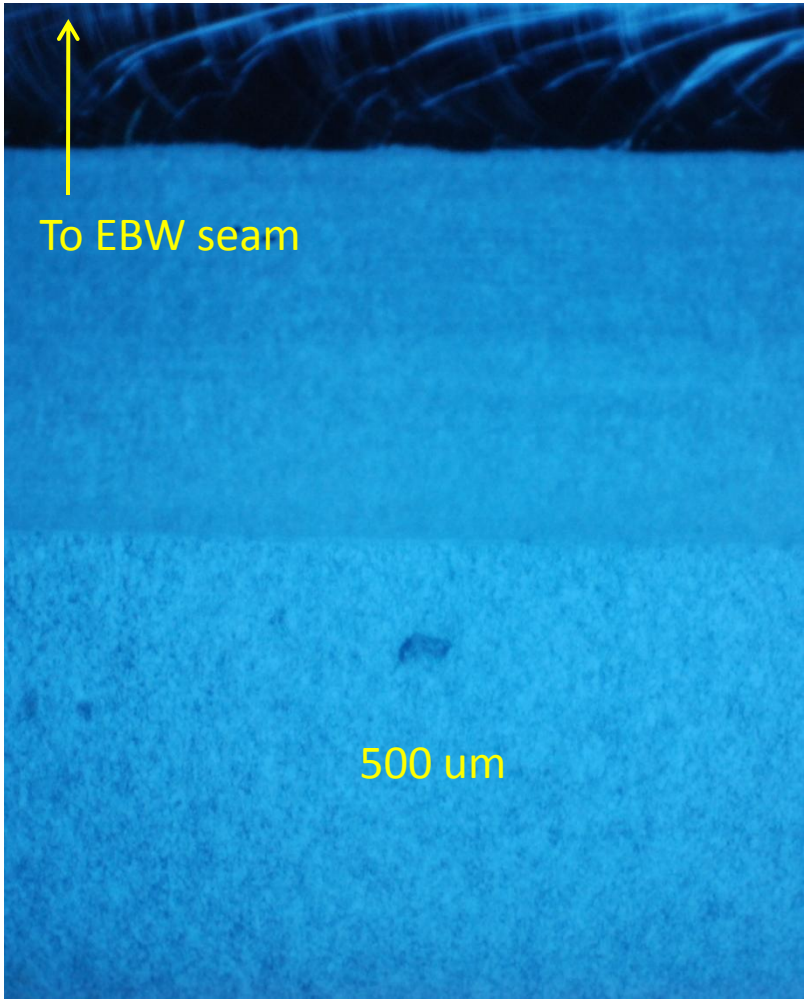




JLab built 9-cell cavity J1 – as built surface

Optical Inspection of As-Built RF Surface

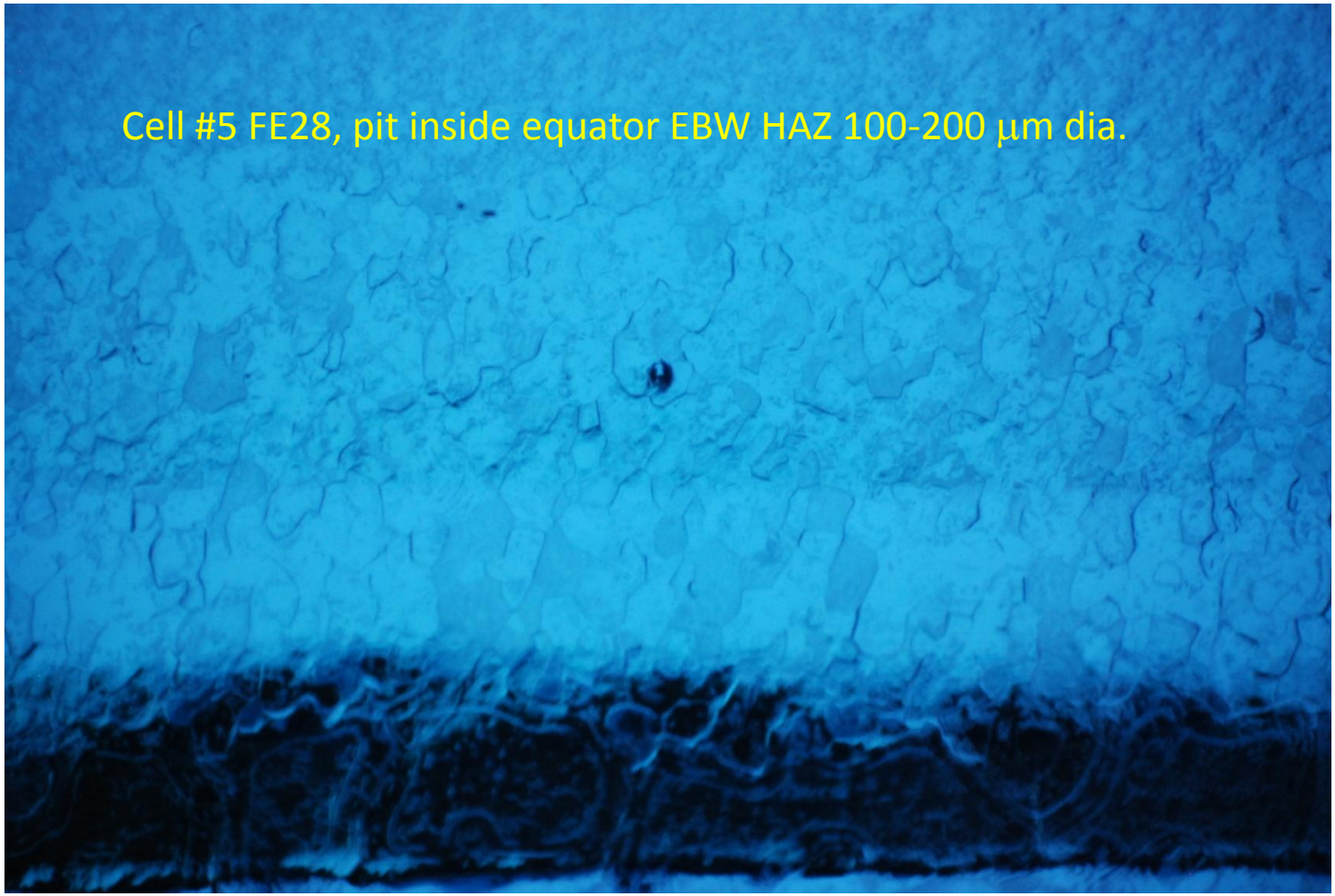




AES6 as built – inspection to be repeated after bulk EP

A13 Bulk EP + 600CX10hr Full Inspection

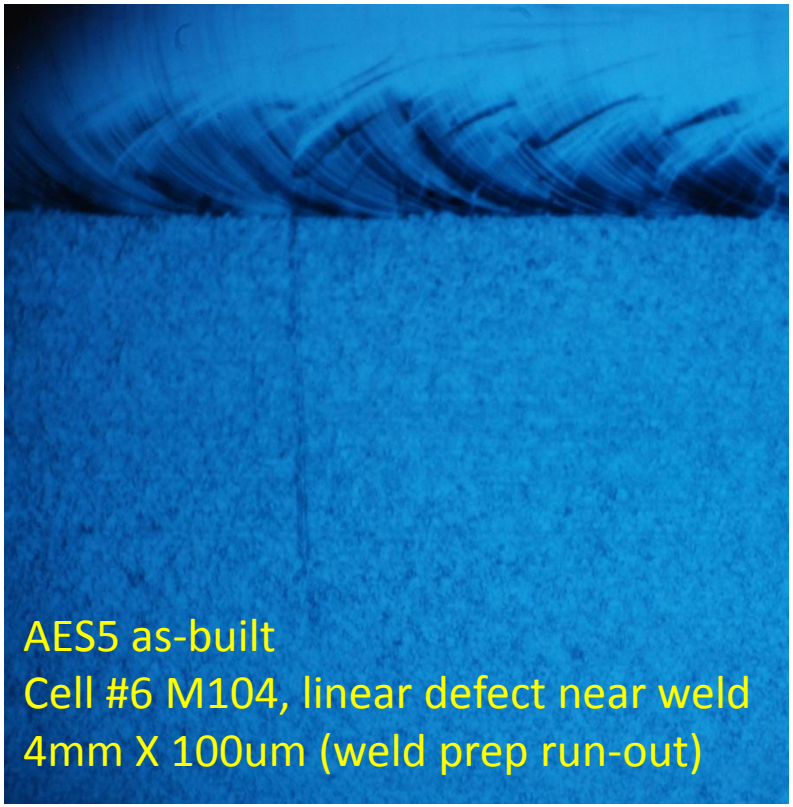
many pits of various sizes (50-200 μm dia.) inside & outside equator EBW HAZ

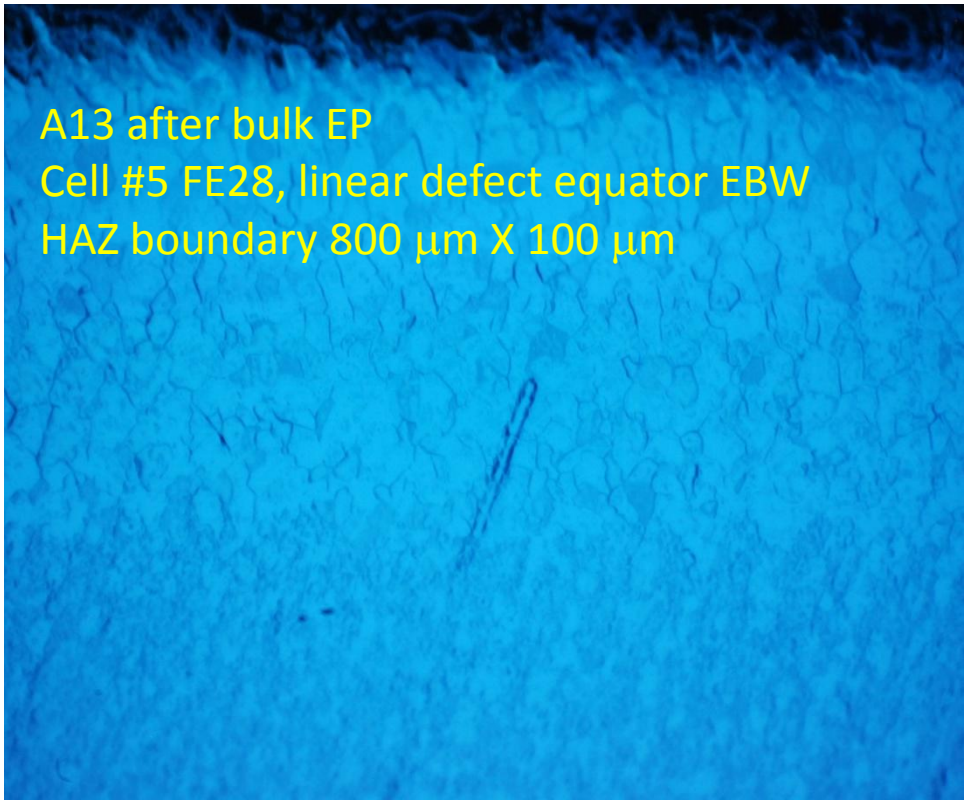


A13 was later light EP (20-30 um removal) and reached 44 MV/m, further inspection pending

Observation of Linear Defect near EBW

(suspected dislocation sites)





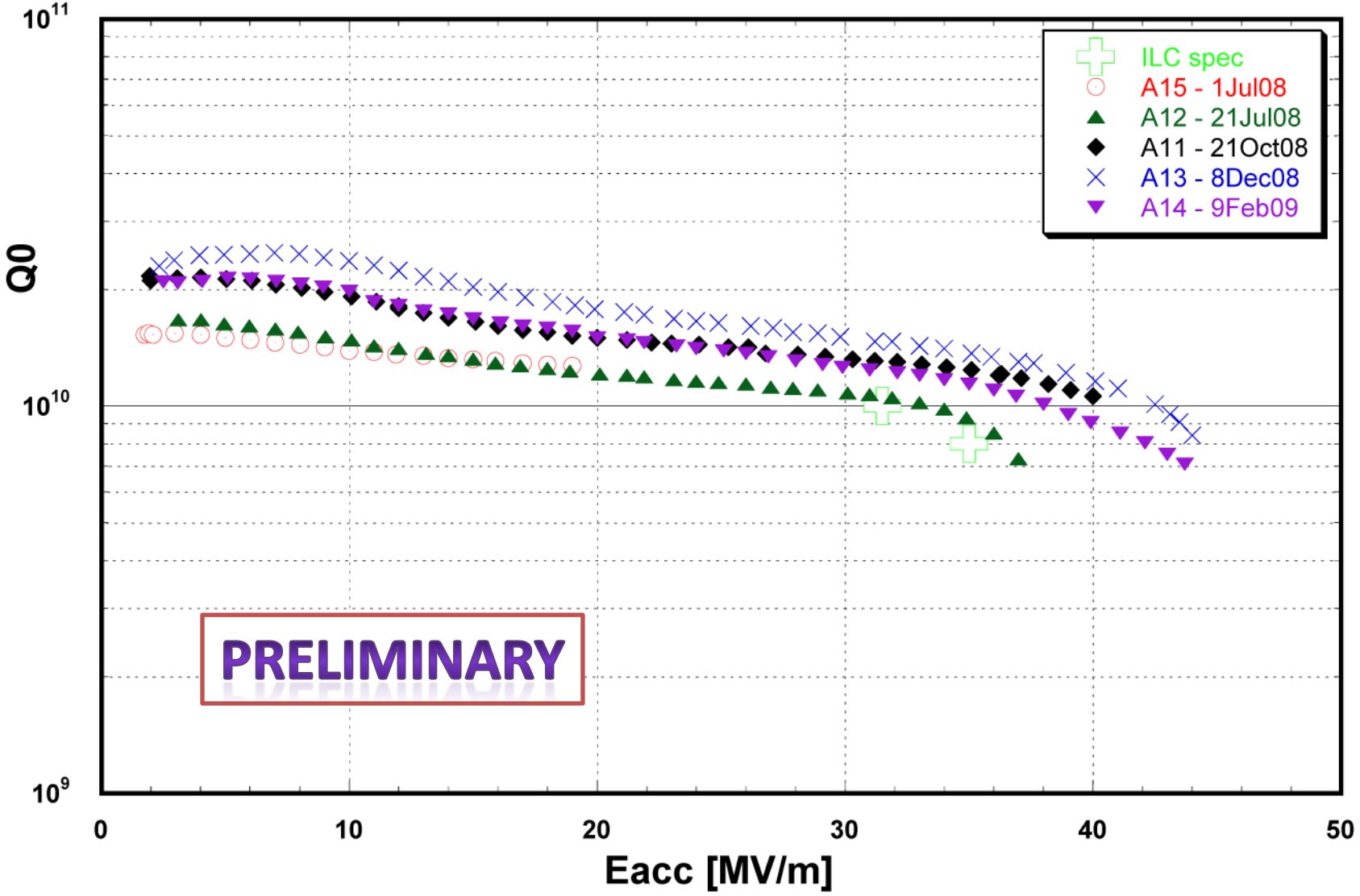
Summary - II

- Sub-mm circular defects already observable in HAZ on as-built surface, as well as on bulk EP processed surface.
- This seems to support theory of defect creation in HAZ due to material/manufacture (instead of surface proc.).
- However, a large number of features are observable in HAZ on as-built surface.
- Studies just began to enable prediction of quench inducing defects.
- I expect the cavity manufacturer in industry is able to control defects once we tell them what kind of defects are not tolerable.

Summary – II (cont.)

- JLab's demonstrated 9-cell cavity EP & VT capability (30 cycles per year) useful for pushing "processing yield".
- For example the excellent yield demonstrated by the six 9-cell cavities (A11, A12, A13, A14, A15) built by one vendor, EP and VT at JLab (next slide).
- Our EP/VT capability now enhanced w/ routine T-mapping & high-resolution optical inspection to pave path for improved "production yield". J1 and AES6 are the first 9-cell cavities along this line of research.
- I expect close collaboration between labs and industry will be beneficial and necessary for us to win the battle against quench at ~ 20 MV/m.

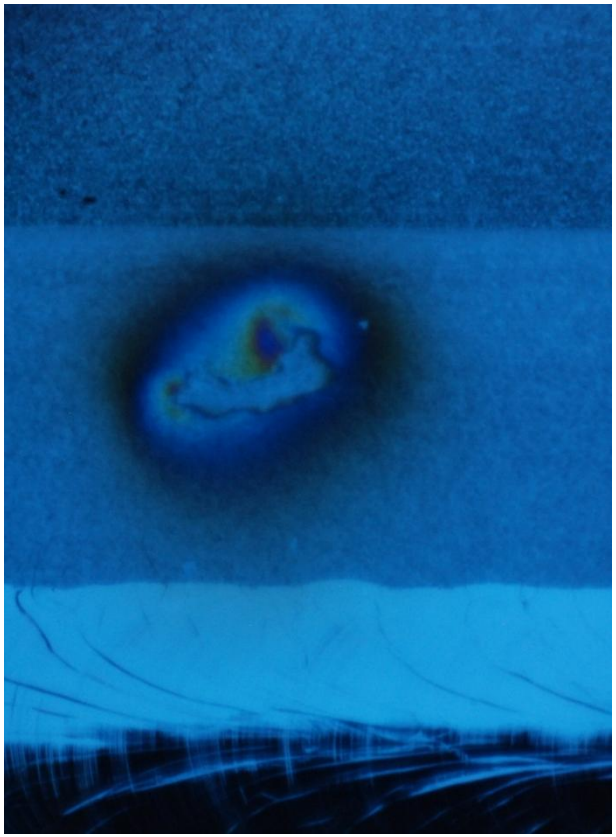
One Vendor Cavity (5) Performance in Last 8 Month, EP/VT at JLab – only one light EP prior to RF test



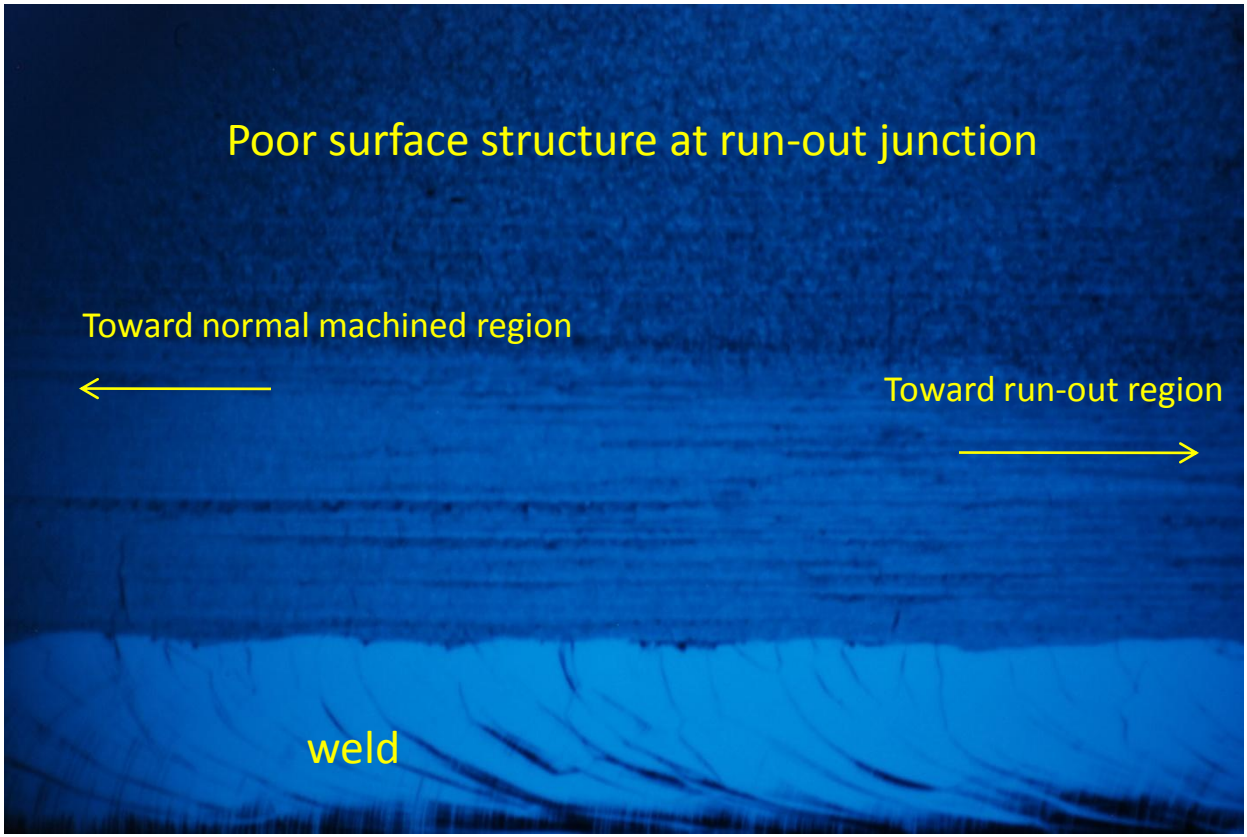
Final Remarks – Don’t Forget “Simple” Things

Irregularities from Machining/Welding

weld spatter

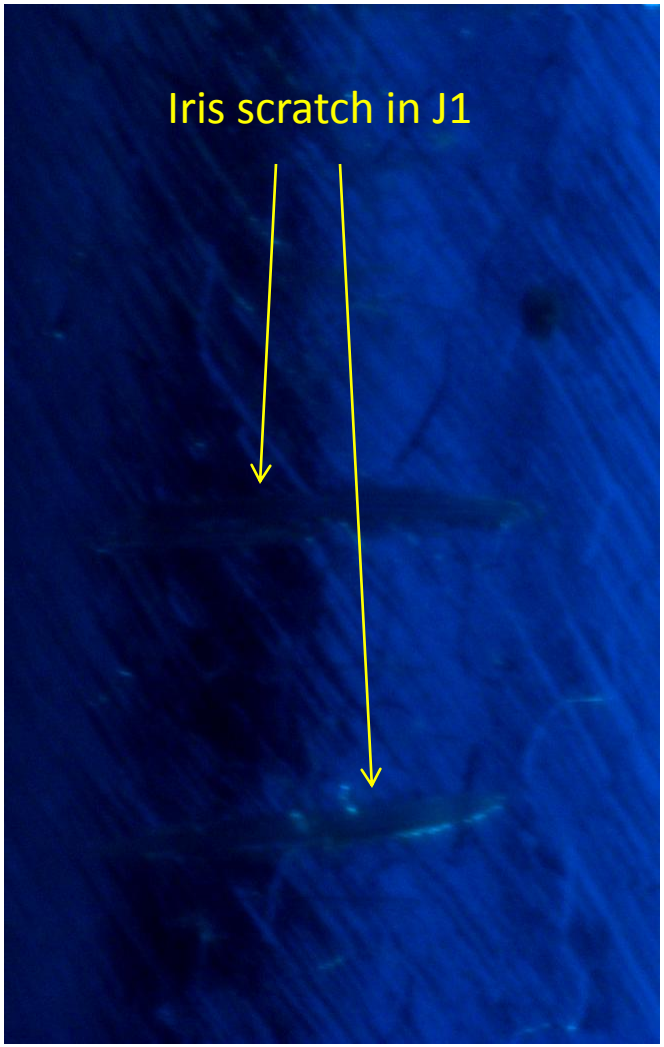


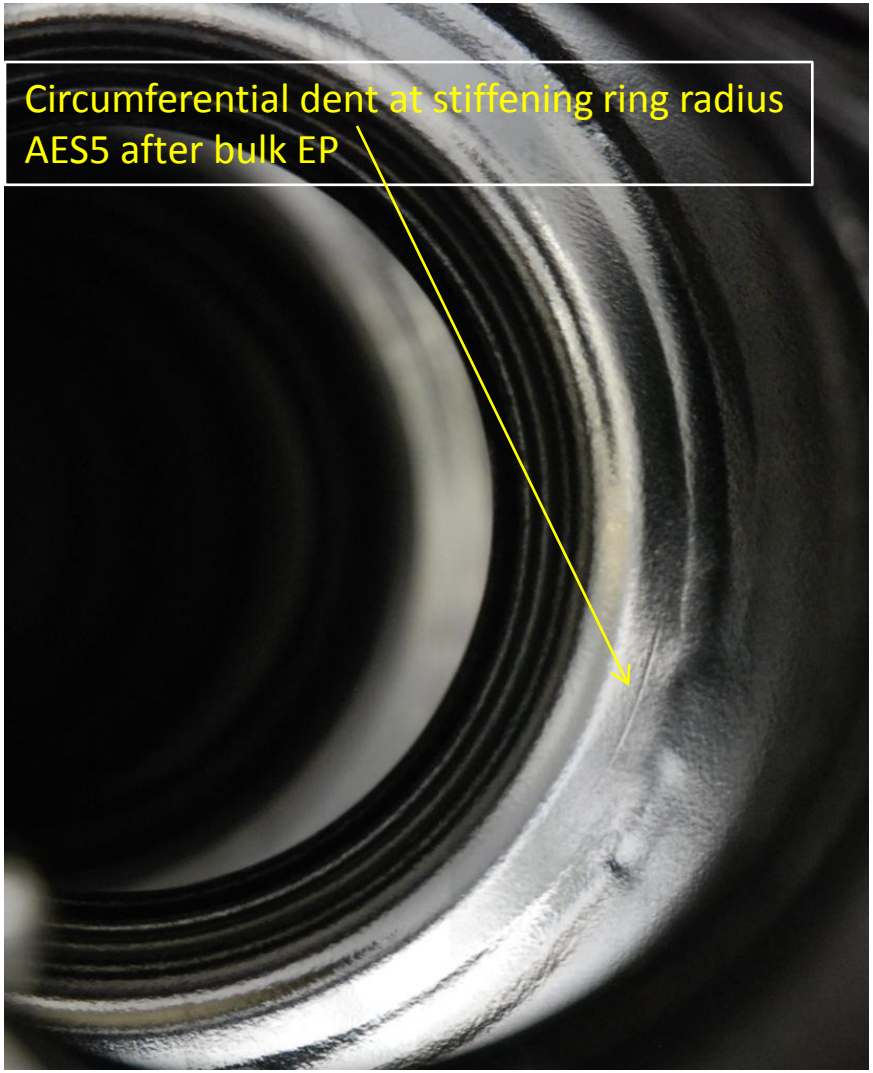
Weld prep machined region run-out



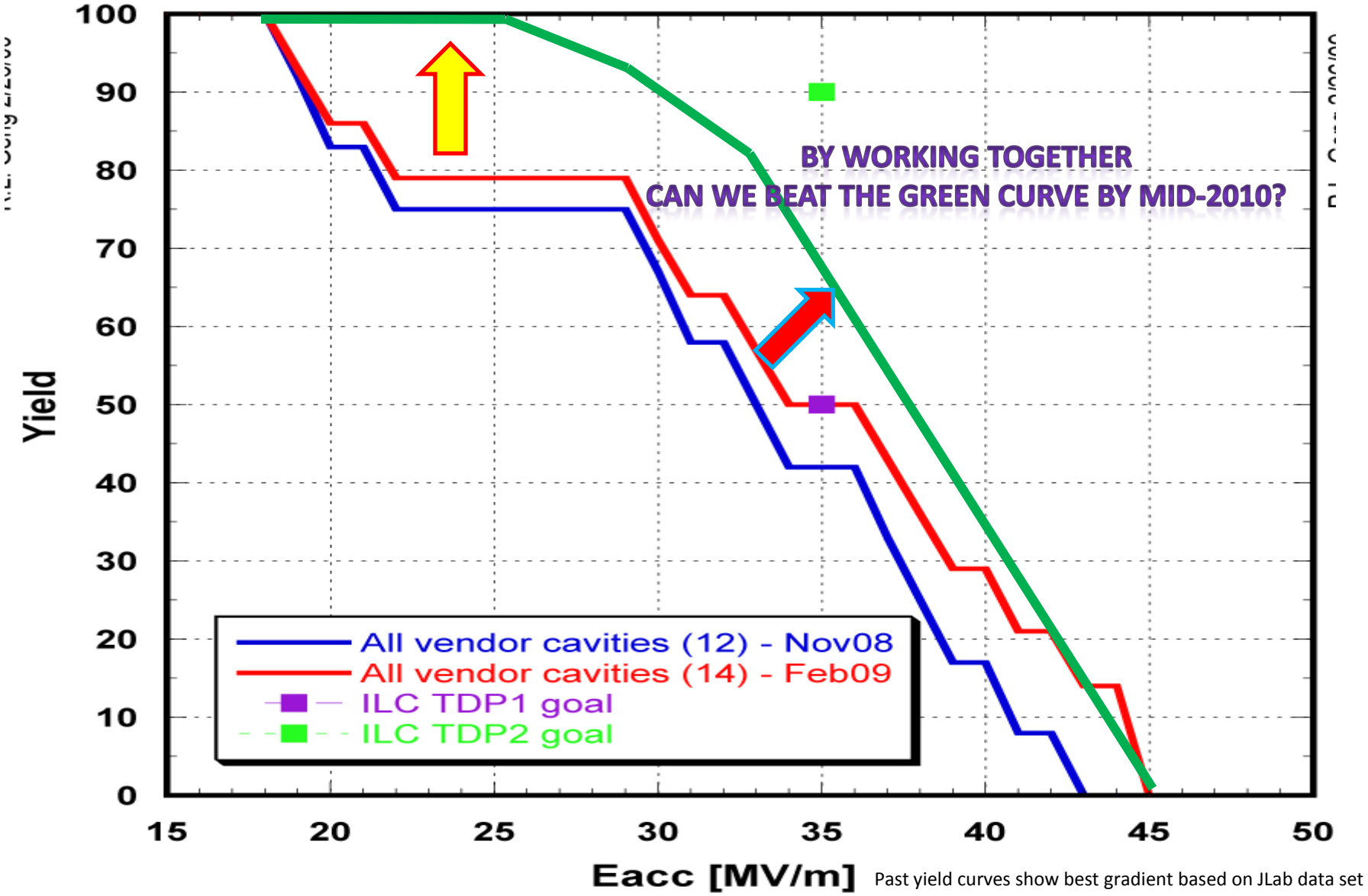
Final Remarks – Don’t Forget “Simple” Things

Damages from Handling/Fixture





Two Big Pushes Ahead…



Past yield curves show best gradient based on JLab data set